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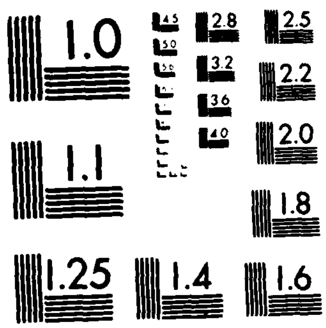

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LITHIUM BATTERY SAFETY-A FIBER-OPTIC APPLICATION FOR SAFE OBSERVATION OF LITHIUM CELLS UNDER SEVERE TESTS

BY MORTON STIMLER

RESEARCH AND TECHNOLOGY DEPARTMENT

10 JANUARY 1984

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This report documents an experimental concept related to lithium battery safety. The concept should allow remote visual display of components inside lithium cells while under test conditions.

The purpose of the proposed experiment is to provide a safer means for observing the internal components of lithium cells under various test conditions including destructive testing.

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FOREWORD

This report documents an experimental concept related to lithium battery safety. The concept should allow remote visual display of components inside lithium cells while under test conditions.

The purpose of the proposed experiment is to provide a safer means for observing the internal components of lithium cells under various test conditions including destructive testing.

It is anticipated that presentation of this experimental concept to researchers working in the area of lithium technology will lead to its application and improvement where necessary.

Approved by:

J. R. Dixon

JACK R. DIXON, Head
Materials Division

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ILLUSTRATIONS

CHAPTER 1

INTRODUCTION

BACKGROUND

At this time it is well-known that the ability to safely substitute lithium batteries for existing batteries in many Navy systems would provide numerous technological improvements in system capabilities (Reference 1).

Lithium batteries provide considerably higher energy densities, per unit weight and volume, than existing batteries. In addition, they can be discharged at high rates with excellent voltage regulation and over a wide temperature range. Furthermore, their storage life is long, even without refrigeration (Reference 1).

At the current time, however, there are certain hazards associated with lithium cells and batteries. Among these are fires, toxic gas venting and, under certain conditions, explosions due to high internal pressure buildup.

These hazards must be eliminated before lithium batteries can be used in Navy systems. Unfortunately, the reasons for their existence are not fully understood at the present time.

One approach toward the solution of these problems is an intensive investigation into a better understanding of lithium electrochemistry (Reference 2). A second approach was recently suggested by D. D. Lawson of the Jet Propulsion Laboratory at Pasedena, California. He proposed an experiment to listen to the cells, with acoustic detectors, for noises under test conditions which might indicate cell breakdown.

The fiber-optic application described in this report is proposed as a third technique which might be used to contribute toward the understanding and elimination of the existing hazards. It provides direct visual observation of the internal cell components under test conditions. In the event of some internal cell breakdown, for example, this technique would provide information as to the location and nature of the malfunction by remote viewing.

This concept was recently presented at a meeting with R. F. Bis and D. L. Warburton (Naval Surface Weapons Center) both of whom contributed helpful suggestions to improve it for lithium battery study.

CHAPTER 2

THE FIBER-OPTIC CELL

EXTERNAL VIEW

Figure 1 shows a production design of a conventional lithium sulfur dioxide (Li/SO_2) cell. It is formed of a spirally wound anode and cathode. The anode is a rectangular strip of lithium foil. The cathode is a teflon-carbon mix pressed on a supporting aluminum screen. The electrodes are separated by micro-porous polypropylene separators as shown. The cell case is provided with a rupture vent as a safety precaution against violent shell case rupture in the advent of high internal pressure buildup (Reference 3).

An external view of the proposed experimental cell is shown in Figure 2. A split fiber-optic bundle is shown entering the cell. One bundle is for carrying the image from the cell for remote display on a low-light-level television (L^3 TV) screen. The second fiber-bundle, referred to as the "illuminating light input bundle" in Figure 2, provides a means for internal illumination of the cell. Electrical output terminals are provided for prescribed electrical tests. A rupture vent is also provided, as in the production design, for safety against internal pressure buildup.

SECTIONAL VIEW

Figure 3 is a sectional view showing the internal structure of the proposed cell. It is rectangular in cross section with plane-parallel anode and cathode (rather than spirally wound) as a suggested first model of the concept. Any resulting reduction in battery rate capability and capacity would be accepted for these tests. In this configuration the lithium anode is to be observed under test conditions. This is of interest because of the suspected possibility that one source of at least some of the previously mentioned hazardous conditions is the formation of pinholes in the dithionite coating on the lithium anode. This coating normally separates the lithium from the electrolyte. The pinhole condition may occur, for example, during a high discharge current pulse. This would be one of the tests performed. During such a test the remote TV display would be continually monitored and video-recorded.

The cutaway view in Figure 3 shows the important feature of the fibers passing through the carbon collector cathode. This is possible because as previously described, this electrode is porous, being formed of a teflon-carbon mix pressed on an aluminum screen grid. This provides a solution to the problem of high transmission losses in the optical fibers which would be introduced by small-radius bending of the fibers. Such bending of the fibers would be

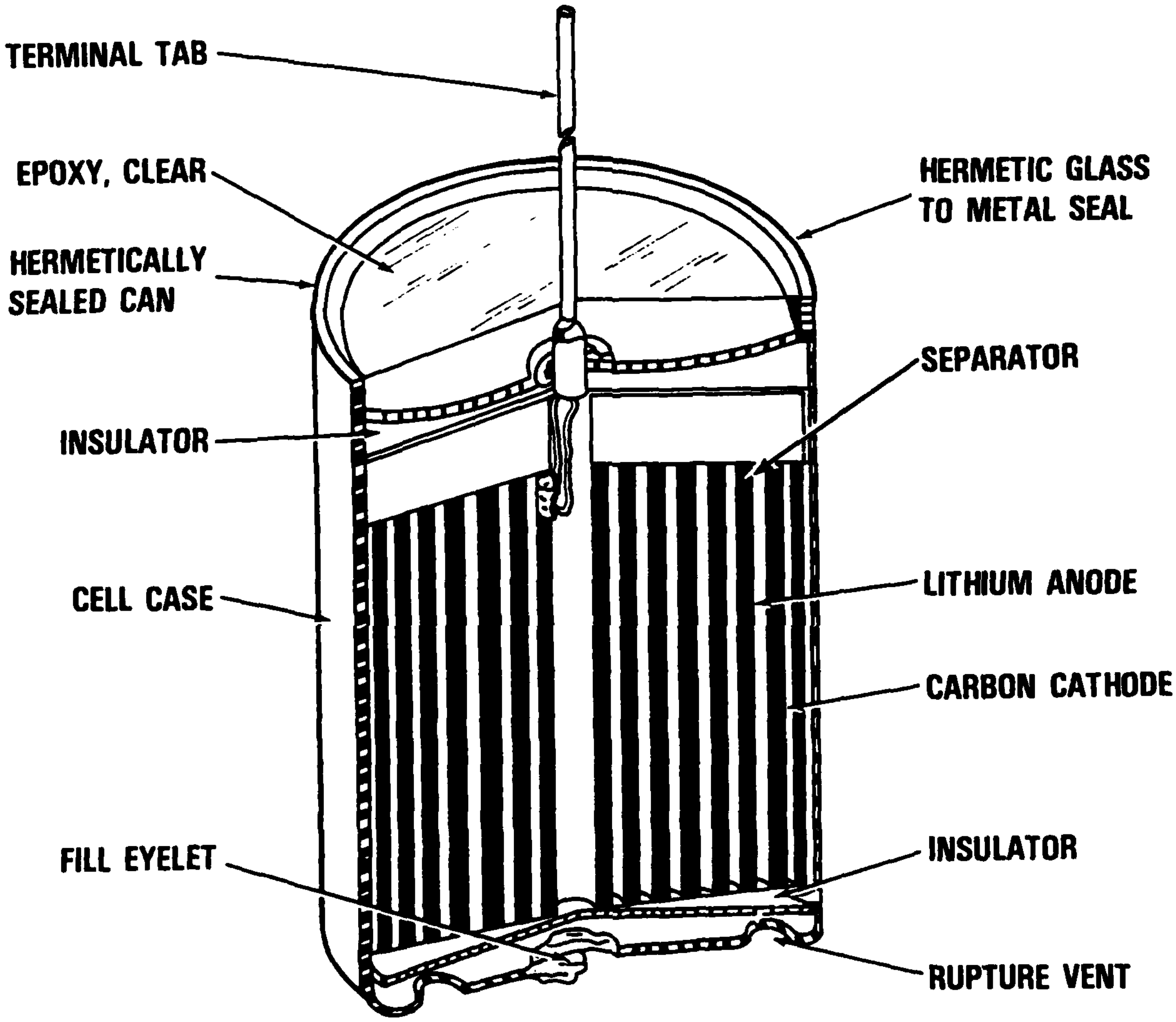

FIGURE 1. LITHIUM-SULFUR DIOXIDE CELL

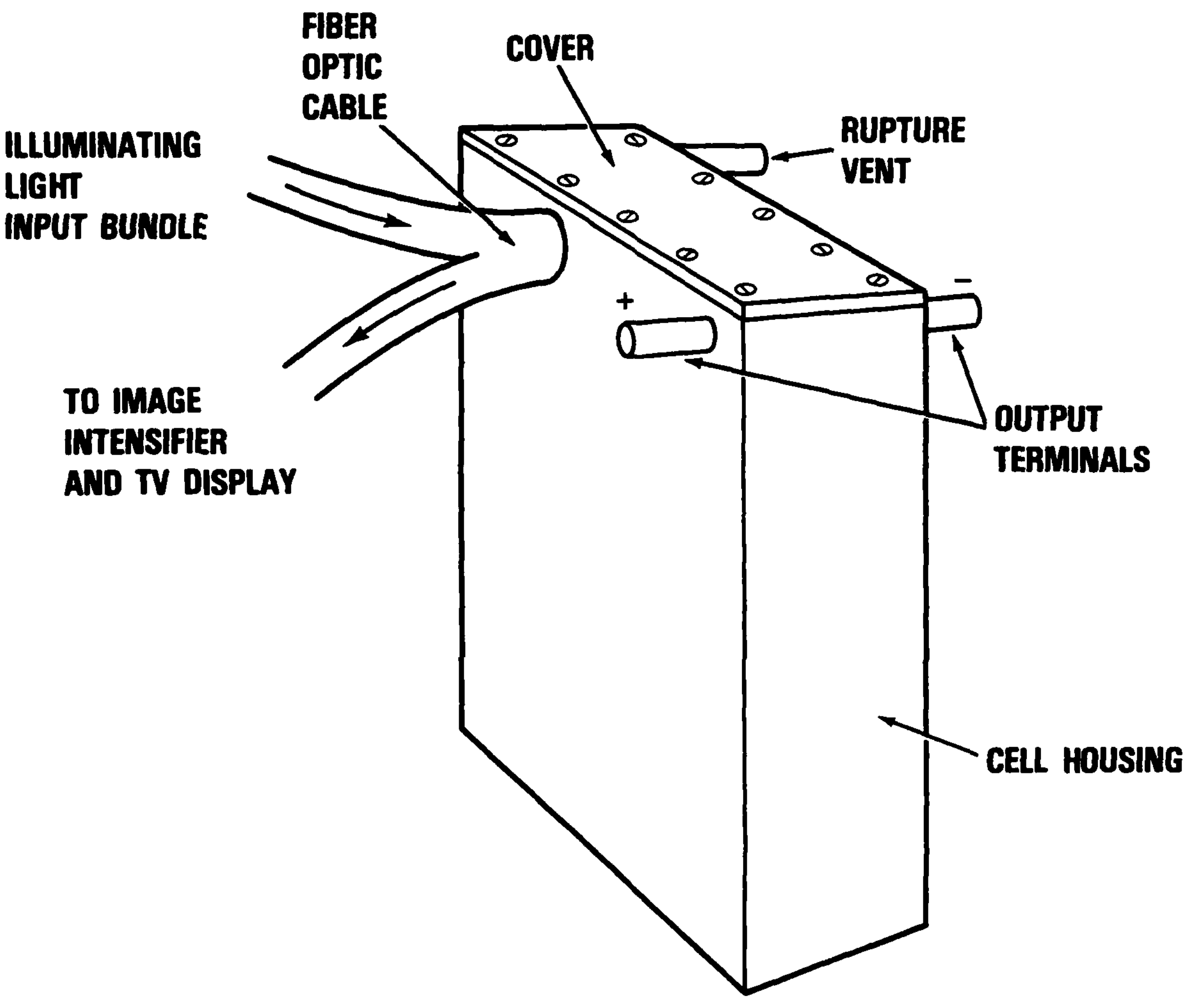

FIGURE 2. CONCEPTUAL SKETCH OF EXPERIMENTAL LITHIUM CELL

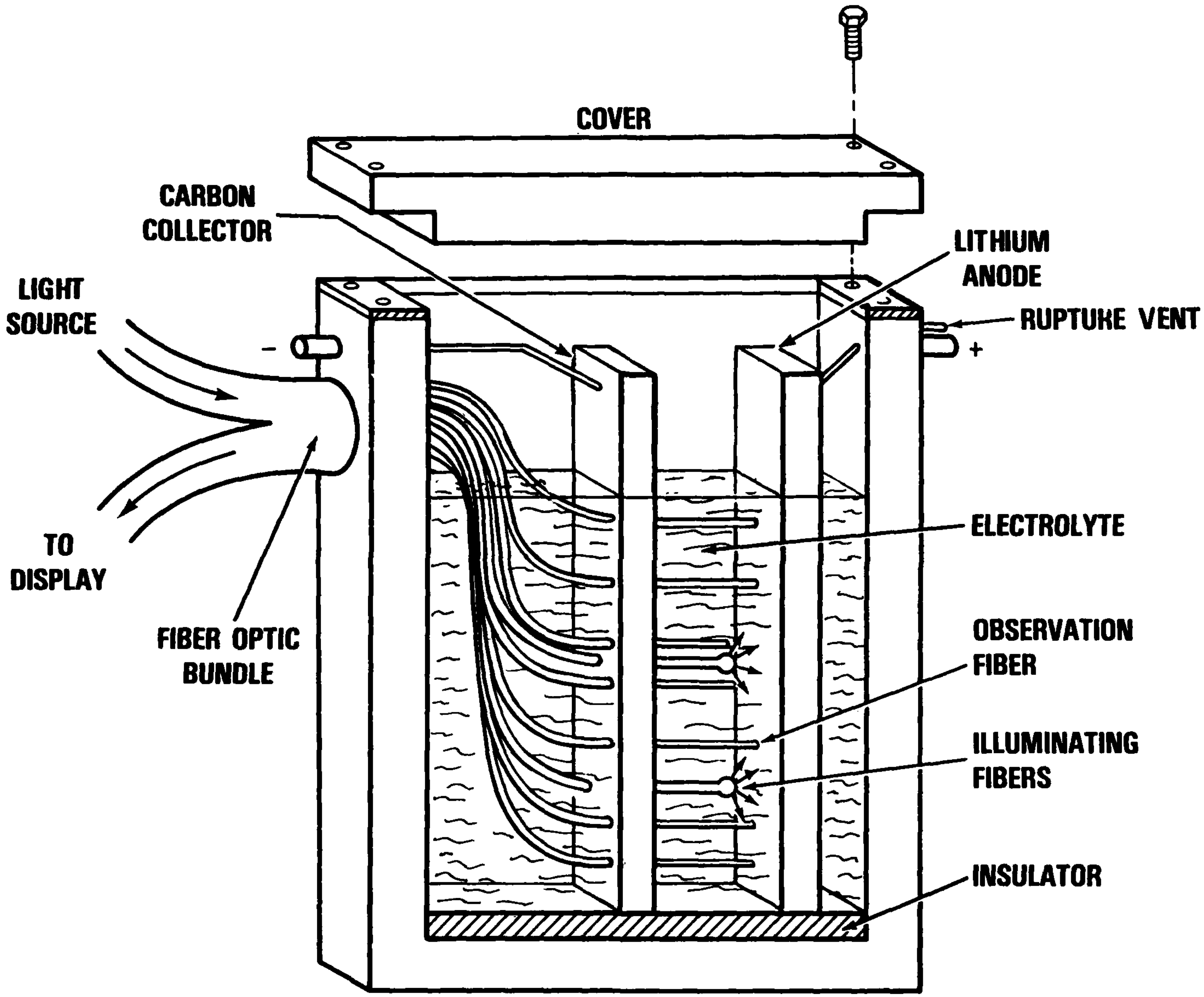

FIGURE 3. SECTIONAL VIEW OF EXPERIMENTAL LITHIUM CELL

required if the fibers were to be placed between the anode and cathode. By the technique shown in Figure 3, the fibers may be brought out of the cell with a relatively large-radius bend, and the anode to cathode spacing may be made small to increase the battery capacity and rate capability.

Figure 4 is a front view of the carbon cathode collector showing the array of optical fibers. The illuminating fibers are shown uniformly distributed over the collector area for the purpose of illuminating the entire area of the anode to be observed. The observation fibers, as indicated, are also uniformly distributed.

With regard to physical construction of the cell, Figure 3 shows the carbon collector providing the total support of the fibers passing through it. In the engineering design, an additional support plate for the fibers may be required. Such a support plate would be located to the left of the carbon collector in the orientation shown in Figure 3. It should also be noted that the fibers are illustrated conceptually in Figures 3 and 4 and are not necessarily single fibers. For example, they may each be small fiber bundles such as used in commercially available imaging fiber optics. The illuminating fibers are illustrated in Figure 3 as spherically terminated. This is for the purpose of diffusing the illuminating light and spreading it over the area to be observed, particularly for small electrode separations. The spherical termination has been chosen as a first approximation. In actual use the optimum termination may be some other shape, for example, convex-lens form rather than spherical.

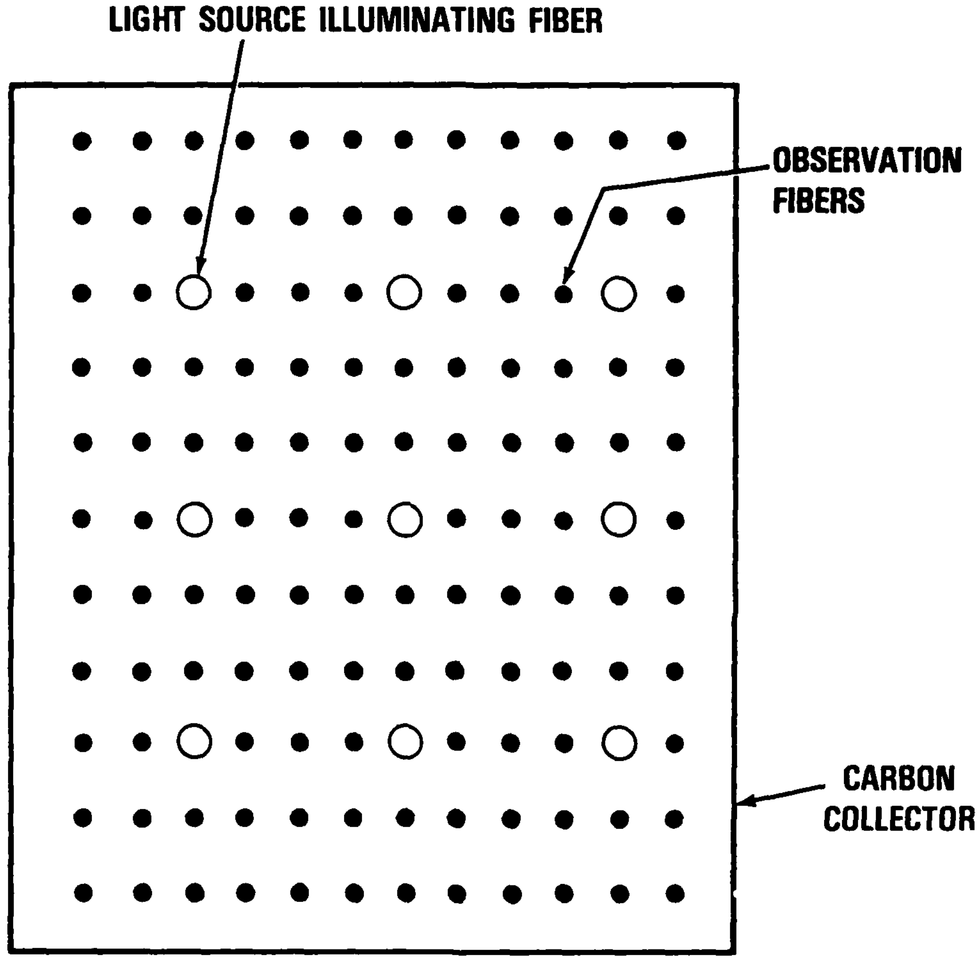

FIGURE 4. FRONT VIEW SHOWING DISTRIBUTION OF ILLUMINATION AND OBSERVATION FIBERS THROUGH CARBON COLLECTOR

CHAPTER 3

SYSTEM

Figure 5 shows a block diagram of the system in which the experimental lithium cell is to be observed. An optical source illuminates the cell through the previously described fiber-optic (input) line. An electrical test load is shown applied to the terminals of the cell. The image of the cell anode is transmitted by the fiber optic (output) line to an IR converter and image intensifier, and from there to a TV display and video recorder.

It should be noted that a display may be achieved with other than visible illumination. For example, if the fiber optic lines have maximum transmission efficiency at a particular wavelength range in the infrared, then the illuminating source would be of that wavelength range. The image would then also be an infrared image to be up-converted for a final visible display. This would be accomplished by the "IR Converter and Image Intensifier." The converter and image intensifier have been shown in the same block since these functions are often performed at the same time in conventional infrared-to-visible image converters. The image intensifier provides the low light level capability.

In applications using integrated optics, GaAs light emitting diodes (LEDs) are often used as light source inputs to fiber optic lines having maximum transmission matching the LED output wavelength. For GaAs this corresponds to a wavelength on the order of 0.85 micron.

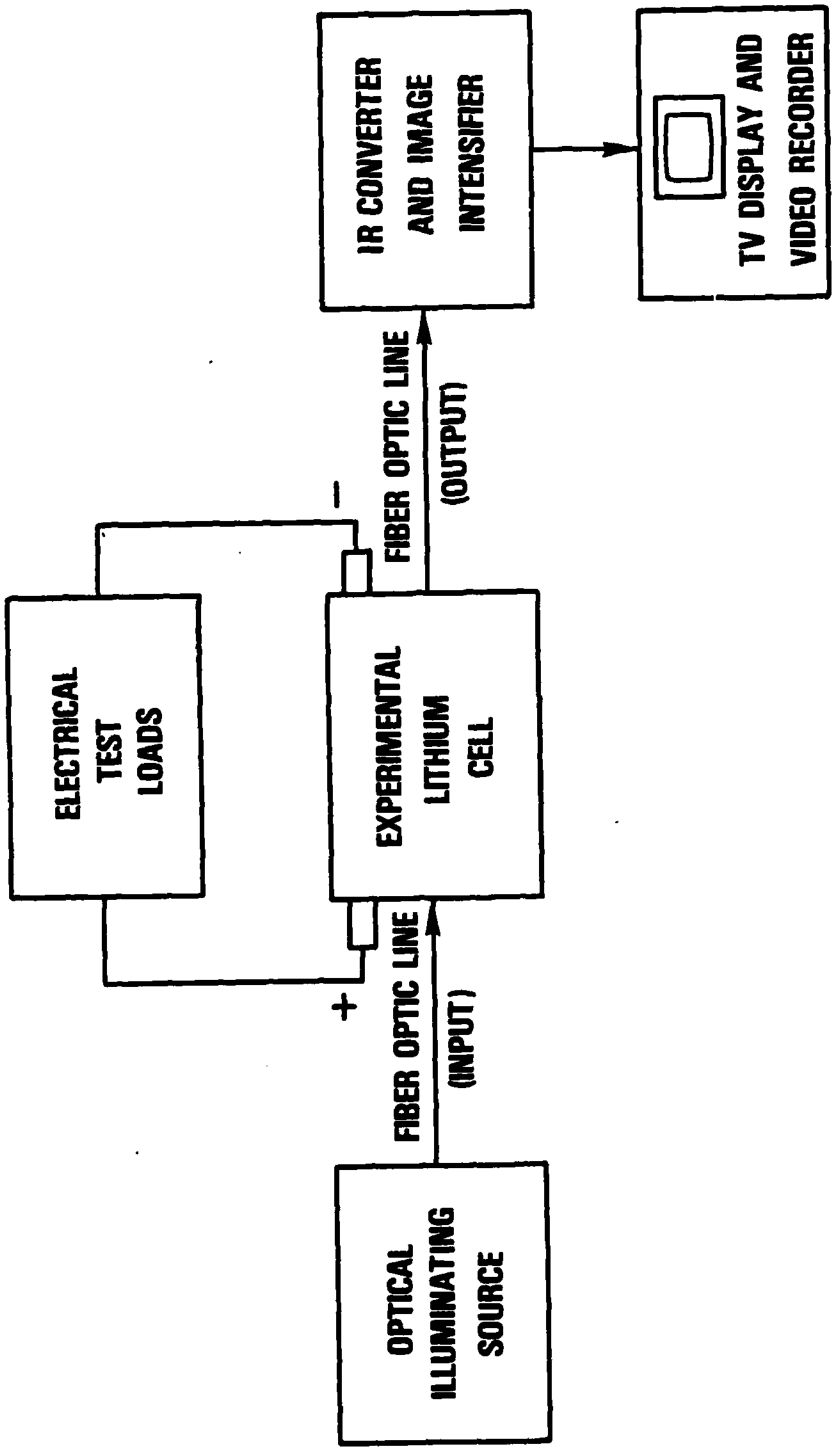

FIGURE 5. BLOCK DIAGRAM OF LITHIUM CELL EXPERIMENTAL SETUP

CHAPTER 4

ALTERNATE FORMS

In the event that other cell configurations may be of interest, the proposed experimental cell may be modified while retaining the features described in this report.

Figure 6 shows an example of how the cell might be adapted to concentric-cylinder form. The fiber optics would be brought in axially. The observation and illumination fibers would then pass through the inner carbon cathode perpendicular to the cell axis. They would thus be in position to illuminate and observe the outer lithium electrode, thereby maintaining the previous design features and concept of the cell. This cylindrical design shown in Figure 6 could be extended to spiral form to simulate the production design shown in Figure 1 if desired.

One example of why there might be an interest in different mechanical shapes is the following:

Assume that a fiber-optic cell with plane-parallel electrodes, such as described in this report, does not reproduce previously referenced hazardous conditions. This could be properly interpreted as a positive result, indicating that at least some of the hazard problem might be in the mechanical construction of the production design. This is not generally considered to be a cause of the lithium cell problems at the current time. However, the tightly wound spiral of lithium, the teflon-carbon mix on the aluminum screen, and the separator are all dissimilar materials. Under changing temperature conditions, differences in thermal expansion could result in internal stresses causing possible breakdown of the dithionate coating on the lithium anode. As pointed out in Chapter 1, such a breakdown is suspected as a source of hazardous conditions. Although the suspected cause is thought to be chemical in nature, it is possible that it may be mechanical. This may be pursued by observing various electrode shapes designed to amplify mechanical effects.

At the current time data is not available to indicate that internal mechanical stresses exist or may be caused, for example, by dissimilar coefficients of thermal expansion of cell components. This is one of the areas where useful additional information could be acquired by application of this fiber-optic cell concept.

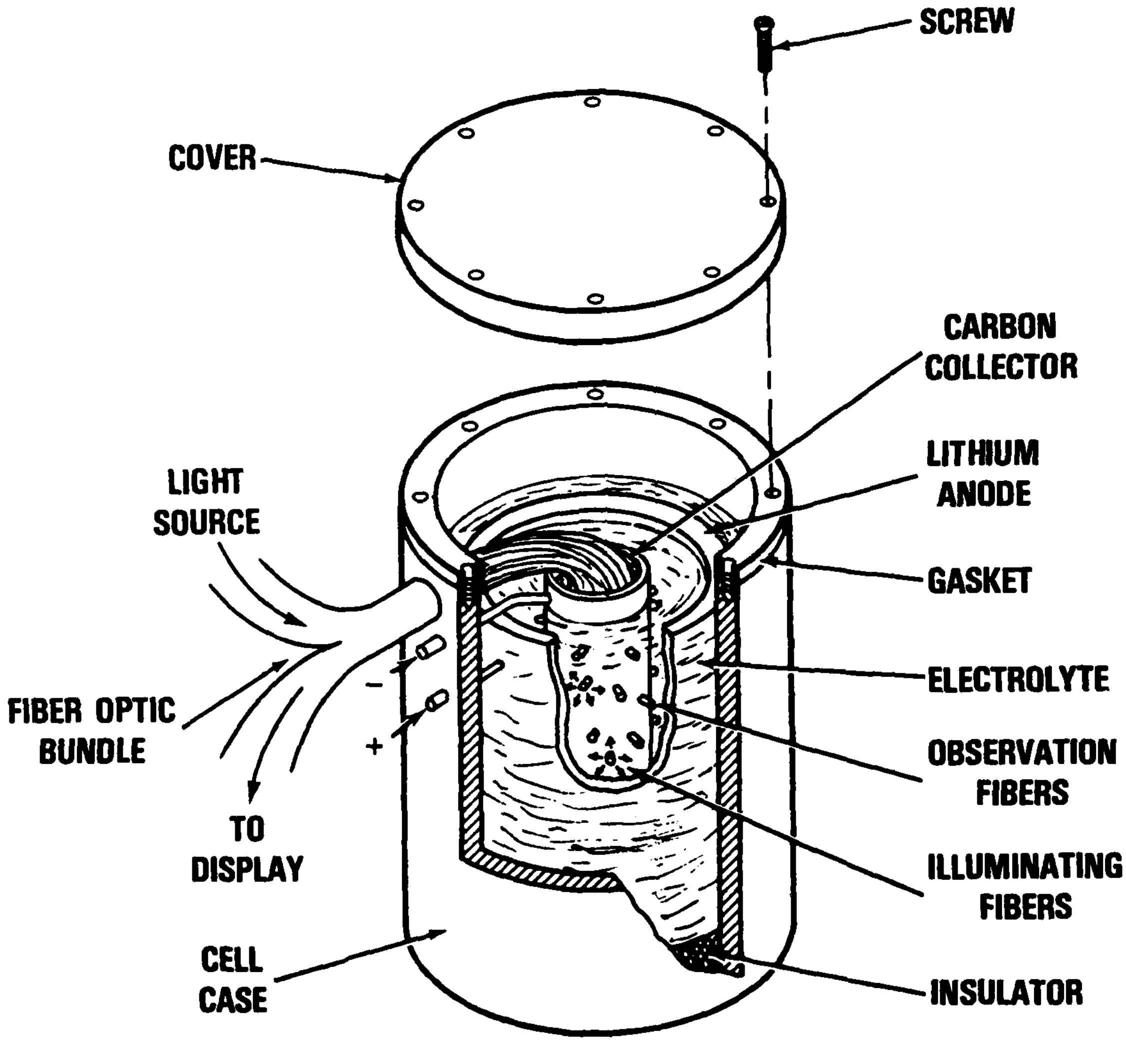

FIGURE 6. ALTERNATIVE METHOD OF EXPERIMENTAL CELL CONSTRUCTION

CHAPTER 5

SUMMARY AND RECOMMENDATIONS

An application of fiber optics is presented for use in the study of lithium cells as related to lithium battery safety. A brief background gives the advantages and the hazards of lithium batteries. The proposed experimental-cell concept is presented and described in detail. The routing and distribution of the fiber optics inside the cell is illustrated, showing a divided fiber bundle to provide illumination as well as imaging. The system is then described showing the system components needed in addition to the cell. Alternate forms of design are then discussed giving an illustration of a cylindrical design. An example is then given of why different design shapes might be useful. The example suggests the possibility of mechanical stresses due to different coefficients of thermal expansion of the dissimilar components in the spiral wrapping of a production cell.

The following recommendations are made with reference to the engineering design of the fiber optic cell described in this report:

1. Maximum optical transmission may occur at wavelengths other than in the visible range. It is therefore recommended that transmission windows be determined from the absorption spectrum of the cell electrolyte being used.

2. A fiber optic cable should then be chosen which has its transmission wavelength band matching one of the electrolyte transmission windows.

3. The transmission wavelength which is chosen should also be capable of conversion to a visible wavelength for observation.

4. It is further recommended that the organization selected to build and test the cell should have IN-HOUSE fiber optic capability as well as a working familiarity with lithium cell safety test procedures.

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